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Finite element analysis of the structure of an electronic equipment shelter

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Abstract. Due to the special structure of the shelter, the cost of trial production and experimentation in the design stage is very high. In order to research the static characteristics of the electronic equipment shelter, the structure of the electronic equipment shelter is discussed. The ANSYS finite element analysis software is used to establish the equivalent finite element model of the overall structure of the electronic equipment shelter and the bearing platform. The static simulation of the body structure under specific working conditions is carried out, and the stress and strain state are obtained. At the same time, the modal superposition method is used to analyse the overall transport vibration response spectrum of the electronic equipment shelter and the bearing platform. The results show that the maximum stress value of the electronic equipment shelter is less than the allowable stress, and the maximum deformation is also in full compliance with the requirements. At the same time, it meets the requirements of the transportation vibration environment adaptability of the electronic equipment shelter, and provides design reference for the similar electronic equipment shelter.

1. Structural design of electronic equipment shelter and carrying platform

1.1. Basic requirements for the shelter

The shelter is to provide installation and transportation platform for the special equipment of the vehicle. The shelter is fixed on the carrying platform by the shelter rotary lock. The carrying platform and the off-road vehicle are rigidly connected and fixed. The shelter is not only the protection body of the special equipment for the vehicle but also its transportation bearing body, as shown in Figure 1, the electronic equipment shelter includes two parts: the shelter and the sub-frame. The shelter is in the form of a large-plate shelter. The sub-frame portion is welded by steel profiles such as rectangular steel tubes and channel steel to form an integral frame. At the same time, four sets of leveling frog legs are arranged on the platform of the shelter, and the whole platform of the carrying platform is removed from the vehicle and relies on the frog legs to ensure the leveling of the entire platform.

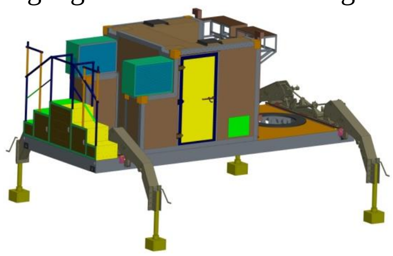

Figure 1. Overall layout of the shelter

1.2. The shelter skeleton structure design

The shelter body is spliced with a large plate structure, the wall thickness is 50mm, and the aluminum plate is used on both sides of the large plate, and the polyurethane foam and the temperature insulation plate are filled in the middle. In order to ensure the inner space of the shelter, a steel platform is used as the bottom plate, and the bottom plate is supported by the platform steel frame, and the inner part of the shelter is made of aluminum plates on both sides, and the middle plate is in the form of a partition plate. The skeleton of the square slab is welded by rectangular steel pipe to meet the requirements of the shelter. The steel frame and the bottom platform of the shelter are sprayed with zinc. Due to the special shape of the shelter and the high requirements on the strength and rigidity of the shelter, the square panels are welded by means of intermittent welding, and the angle aluminum and the wrap angle are spliced by riveting and gluing. The front and rear end plates of the square cabin and the bottom of the left and right side plates are reserved for burying iron, and the bolts are connected with the bottom plate to ensure the strength and rigidity of the shelter. The front and rear end plates of the shelter, the left and right side plates and the bottom plate are connected by angle steel and rivets are glued to ensure the sealing performance of the cabin.

1.3. Bearing platform structure design

The main body of the bottom plate steel platform is welded by 250mm×80mm×9mm channel steel. The local position welded rectangular steel pipe increases the strength and the frame is welded and vibrated. The platform is provided with a radar mount, a frog leg mounting plate, a transport corner piece, and a 3 mm non-slip aluminum plate on the upper part.

2. Finite element analysis of the structure of electronic equipment shelter and bearing platform

In the design of the shelter, it must be considered that it has sufficient strength and rigidity, while at the same time meeting the requirements of the shelter loading, the cost is reduced as much as possible, the weight is reduced and the high performance shelter is designed. In addition, due to the special structure of the shelter, the prototype test is difficult to carry out in the design and development process, and the cost is high. Simulation through finite element analysis software optimizes the design structure, reduces costs and shortens the development cycle.

2.1. Establish the finite element model of structure of electronic equipment shelter and carrying platform

The geometric model of the shelter and the load-bearing platform is abstracted from the actual structure. It is not completely in accordance with the actual shape of the shelter and the load-bearing platform, but the necessary changes and simplifications of its structure according to certain characteristics of its structure which processed to improve the accuracy and reliability of finite element analysis results. In the shelter analysis, in order to reduce the complexity of the analysis, the effects of foam and skin in the slab frame are neglected, so the analysis is conservative. The anti-slip aluminum plate is laid on the upper part of the load-bearing platform. Due to the limited strength of the anti-slip aluminum plate to the load-bearing platform, the influence of the anti-slip aluminum plate is not considered in the structural analysis. The frame material of the load-bearing platform is made of Q345 steel, the frame of the large-body frame is made of Q235 steel, and the outer side of the cabin is made of 6063 aluminum.

When establishing the finite element model of the electronic equipment shelter and carrying platform, the following assumptions were made:

- The material properties of the welds of the electronic equipment shelter and the load-bearing platform are the same as those of the adjacent structural members;
- In order to reduce the complexity of the calculation analysis, the influence of the shelter skin foam and the non-slip aluminum plate on the overall structure is not considered, so the analysis is conservative;

- The joints of equipment as bolts and rivets are subject to complex forces and force transmission, and separate analysis such as contact and extrusion is required. Large-scale structures such as electronic equipment shelter and load-bearing platforms contain a large number of such connections, and it is unrealistic to analyse them one by one, and the results of local connection analysis have little effect on the entire frame system. This type of connection is ignored in this example;
- The deformation of the electronic equipment shelter and the load platform is small deformation.

This analysis mainly considers the static characteristics of the electronic equipment shelter and the load-bearing platform under the load of the antenna and equipment inside the shelter.

2.2. Analysis and calculation of finite element model of the shelter
The overall analysis mode is Static, and the electronic equipment shelter and the load-bearing platform are integrally formed by welding. Therefore, in the finite element model, the contact surface between the profiles is defined by the contact recognition of the workbench, and the contact type is bonded. The Bonded method binds the node degrees of freedom at the joints of the components, the normal direction is not separated, the tangential direction does not allow slippage, and the degree of freedom of the coupled contact nodes.

2.2.1. The shelter finite element model meshing.
According to the size of the shelter model and the grid size, the material property setting and finite element meshing are performed on the model. All 3D solid elements are used in the division.

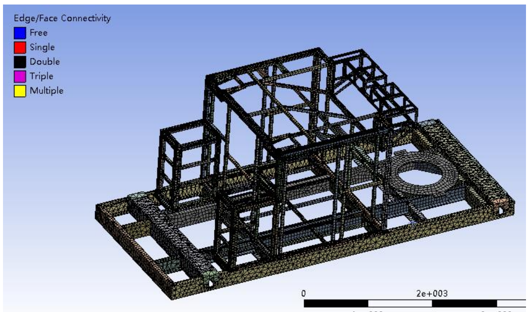

Figure 2. Finite element model of electronic equipment shelter and carrying platform

2.2.2. Material parameters.
The skeleton of the electronic equipment shelter and the load-bearing platform is welded by rectangular steel pipe and square steel pipe, and the shelter part is welded by aluminum profile. The material properties are shown in Table 1 below.

Table 1. Material parameters

Material	Density (kg/mm3)	Poisson's ratio	Yield Strength (MPa)	Modulus of elasticity (GPa)
Steel Q345	7.8 E-6	0.3	345	210
Steel Q235	7.8 E-6	0.3	235	210
Al 6063	2.7 E-6	0.3	160	70

2.2.3. Static analysis.
When performing static stiffness analysis on the electronic equipment shelter and the load bearing platform, the following two conditions are mainly considered:

Working condition 1: The electronic equipment shelter is subjected to 10000N antenna pressure, 8000N cabinet weight, 2500N hydraulic pressure source, 3000N maintenance platform, 30000N antenna weight, 1200N air conditioner external weight and other actual loads.

The contact surface of the fixed constraining electronic shelter and the supporting leg and the contact surface of the electronic shelter and the supporting leg hook are applied, and the load is applied according to actual working conditions. The loading diagram and the stress and displacement diagram are shown in Figure 3.

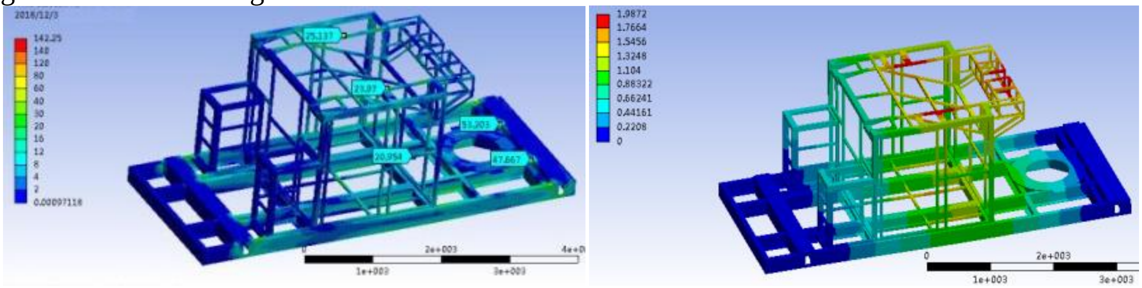

Figure 3. Loading and stress displacement diagram of working condition 1

It is known from the above that under this condition, the maximum stress of the steel frame of the electronic equipment shelter is 142.25 MPa, which is less than the allowable stress of the material 157 MPa (yield strength 235 MPa, safety factor 1.5), and the maximum stress of the aluminum edging is 15.68 MPa, which is less than the material allowable stress: 107 MPa (yield strength 160 MPa, safety factor 1.5). Therefore the structure is safe.

Working condition 2: The load bearing platform bears the weight of 8000N cabinet, 2500N hydraulic pressure source, 3000N maintenance platform, 30000N antenna weight, 1200N air conditioner external weight, 15000N shelter weight, 5000N six meter high reflector wind load, 1500Nm sinusoidal alternation Actual load such as torque.

The contact surface of the fixed constraining bearing platform and the supporting leg and the contact surface of the supporting platform and the supporting leg hook are applied, and the load is applied according to actual working conditions.

During the period of the transmitter perturbation torsion (0-3s), 20 sub-steps (20 sampling points in the time domain) are taken. According to the transient dynamics analysis, the antenna mounting surface torsion angle is within the range of -0.0025° to 0.0023° which is less than 0.1° requires. And the mounting angle of the antenna mount is in the range of -0.73 seconds to 0.79 seconds, which is less than 1 second. Therefore, the load bearing platform meets the requirements of torsional stiffness.

3. Vibration Response Spectrum Analysis of Electronic Equipment Shelter and Bearing Platform

In order to meet the transportation vibration environment adaptability requirements of the electronic equipment shelter and the load-bearing platform, the electronic equipment shelter and the load-bearing platform are determined to withstand the random vibration response during transportation, and the modal superposition method is used to respond spectrum analysis to the electronic equipment shelter and the load-bearing platform. Firstly, the modal analysis is carried out to obtain the natural frequency and mode shape of the electronic equipment shelter and the carrying platform. According to the modal analysis results, the cantilever structure of the bearing platform that affects the natural frequency of the structure is strengthened.

3.1. Modal Analysis of Electronic Equipment shelter and Bearing Platform

In response to spectral analysis, the first 50 modalities are extracted. The excitation load is applied according to the experimental conditions specified in GJB367A. The basic excitation is applied by the constraint; the structural damping ratio is 1.5%. The transport vibration response is shown in Figure 4, and the transport vibration conditions are shown in Table 2.

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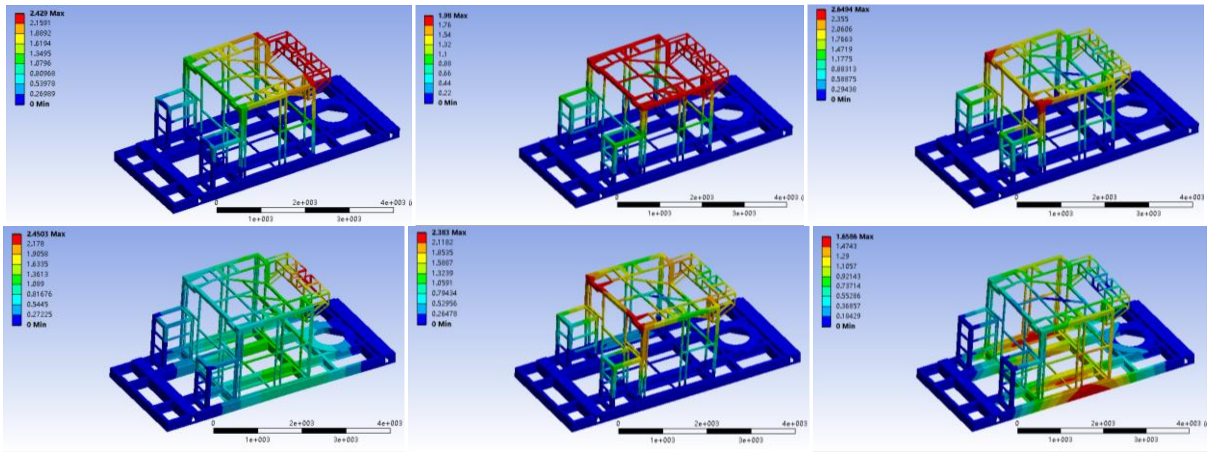

Figure 4. The first six modes of the electronic equipment shelter and the load platform

Table 2. Transport vibration condition

frequency	5-5.5Hz	5.5-200Hz
Amplitude	25.4mm	15m/s^2

3.2. The analysis conclusion of transportation vibration response spectrum
The vibration stress response spectrum stress and displacement distribution of the electronic equipment cabin and the load-bearing platform are shown in Figures 5 and 6.

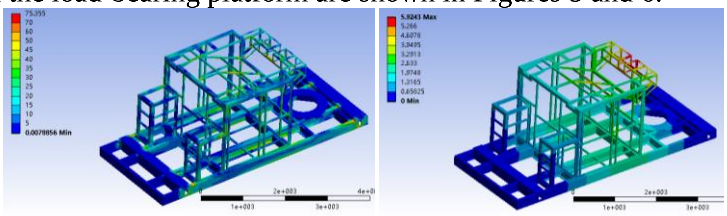

Figure 5. Transportation vibration overall stress and displacement distribution cloud map

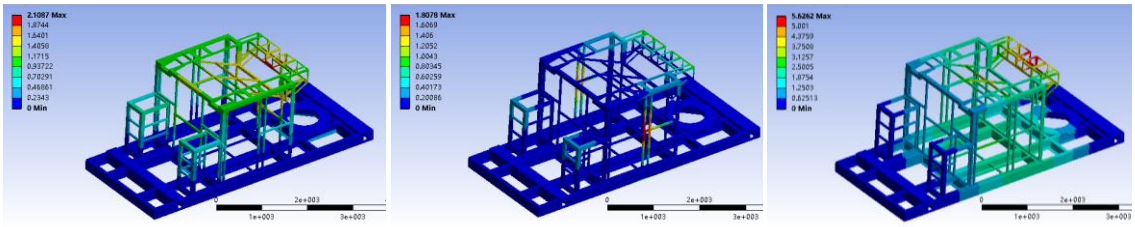

Figure 6. Transport vibration XYZ direction displacement distribution cloud map

It is known from the analysis cloud diagram that during the transportation vibration process, the maximum stress of the shelter is about 75 Mpa, which appears at the bottom of the front end plate. The overall displacement of the shelter and the displacement in all directions shall not exceed 5.9 mm. The rigid strength of the shelter structure meets the requirements.

4. Loading test of electronic equipment shelter and load bearing platform
After the manufacture of the electronic equipment shelter, the loading test was carried out to test the strength and stiffness performance of the shelter and the loading platform, as shown in Fig.7. In the loading test, the load applied on the bottom plate of the tank is 1.5 times of the rated load of the actual

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tank. After 2 hours of loading, there is no phenomenon that the door cannot be opened or the seal is cracked. Tests have shown that the strength and stiffness of the shelter meet the requirements for use.

Figure 7. The shelter loading test

5. Conclusion

In summary, under the above two conditions, the maximum stress of the electronic equipment shelter skeleton under working condition 1 is 142.25 MPa, and the maximum stress of aluminum cladding is 15.68 MPa, which is less than the yield limit of the material, so the electronic equipment shelter design meets the strength and stiffness requirements of the equipment. At the same time, under the working condition 2, the torsion and inclination angle of the mounting surface of the antenna base meet the requirements of the index. Therefore, the bearing platform meets the requirements of torsional rigidity. Finally, through the analysis of transport vibration response spectrum, the maximum stress of the shelter is about 75Mpa, which appears at the bottom of the front end. The overall displacement of the shelter and the displacement in all directions does not exceed 5.9mm. At the same time, the electronic shelter and the load-bearing platform are loaded, So the rigid strength of the cabin structure meets the requirements.

This research provides a reference for the strength check, structural optimization and improved design of the finite element method in the design of the shelter.

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